TITLE OF THE INVENTION

RECIPROCATING PUMP AND VACUUM PUMP

BACKGROUND OF THE INVENTION

The present invention relates to a reciprocating pump that performs suction and discharge of a fluid and a vacuum pump that utilizes this reciprocating pump.

Japanese Laid-Open Patent Publication No. 8-247026, for example, discloses a piston type compressor, which is one kind of a reciprocating pump. This piston type compressor has a conversion mechanism, which converts the rotational driving force of its drive shaft to a driving force in the axial direction of the drive shaft to move the piston back and forth. The conversion mechanism generally has a swash plate. As the swash plate that rotates together with the drive shaft makes one turn, the piston reciprocates once, causing the gas to be sucked into the cylinder bore that retains the piston and discharging the gas retained in the cylinder bore.

Japanese Laid-Open Patent Publication No. 2001-329963 discloses a diaphragm pump. This diaphragm pump causes the diaphragm to reciprocate in the radial direction of the output shaft in accordance with the rotation of the eccentric shaft fixed to the output shaft.

Japanese Laid-Open Patent Publication No. 8-247026 has shoes intervened between the swash plate and the piston. The swash plate slides in abutment with the shoes. The sliding surface of the swash plate that slides in abutment with the shoes is tilted with respect to the axis of the drive shaft. It is therefore difficult to process and form the sliding surface at the time of integrally forming the

drive shaft and the swash plate. Although forming the swash plate and the swash plate as separate components facilitates the processing of the sliding surface, it is troublesome to integrate the drive shaft and the swash plate. In short, it is not easy to produce a conversion mechanism that has projections, such as a swash plate, provided on the peripheral surface of the drive shaft.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a reciprocating pump, which has a simple mechanism and is easy to manufacture, and a vacuum pump that uses this reciprocating pump.

To achieve the above object, the present invention provides a reciprocating pump. The pump has an action chamber having a volume, a volume changing body, a drive shaft and a movable body. The volume changing body defines at least a part of the action chamber and is displaced for changing the volume of the action chamber. Refrigerant is drawn into the action chamber and is discharged from the action chamber in accordance with the displacement of the volume changing body. The drive shaft rotates about its own axis. A groove is formed on a circumference of the drive shaft. The movable body is engaged with the groove and is connected to the volume changing body. When the drive shaft is rotated, the movable body is guided by the groove to reciprocate along the axis of the drive shaft. When the movable body reciprocates, the volume changing body is displaced along the axis of the drive shaft.

The present invention also provides a vacuum pump that draws gas by operating a gas conveying body in a pump chamber through rotation of a rotary shaft. The vacuum

pump has a main pump and an auxiliary pump. The main pump has an exhaust volume, which has an exhaust space for exhausting drawn gas. The main pump has a counterflow prevention mechanism for preventing the couterflow of gas. The counterflow prevention mechanism is located in the exhaust space. The auxiliary pump has an exhaust volume, which is connected to the exhaust space and exhausts gas from the exhaust space. The exhaust volume of the auxiliary pump is smaller than the exhaust volume of the main pump. The auxiliary pump has an action chamber having a volume, a volume changing body, a drive shaft and a movable body. The volume changing body defines at least a part of the action chamber and is displaced for changing the volume of the action chamber. Gas is drawn into the action chamber and is discharged from the action chamber in accordance with the displacement of the volume changing body. The drive shaft rotates about its own axis. A groove is formed on a circumference of the drive shaft. The movable body is engaged with the groove and is connected to the volume changing body. When the drive shaft is rotated, the movable body is guided by the groove to reciprocate along the axis of the drive shaft. When the movable body reciprocates, the volume changing body is displaced along the axis of the drive shaft.

Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred

embodiments together with the accompanying drawings in which:

Fig. 1 is a side cross-sectional view of a root pump according to a first embodiment of the present invention;

Fig. 2 is a horizontal cross-sectional view of the root pump in Fig. 1;

Fig. 3 is a cross-sectional view along the line 3-3 in Fig. 2;

Fig. 4 is a cross-sectional view along the line 4-4 in Fig. 2;

Fig. 5 is a cross-sectional view along the line 5-5 in Fig. 2;

Fig. 6 is a partly enlarged cross-sectional view of the root pump in Fig. 1;

Fig. 7 is a partly enlarged cross-sectional view of the root pump in Fig. 1;

Fig. 8 is a partly enlarged cross-sectional view of a root pump according to a second embodiment of the invention;

Fig. 9 is a partly enlarged cross-sectional view of a root pump according to a third embodiment of the invention;

Fig. 10 is a partly enlarged cross-sectional view of a root pump according to a fourth embodiment of the invention;

Fig. 11 is a partly enlarged cross-sectional view of a root pump according to a fifth embodiment of the invention;

Fig. 12 is a partly enlarged cross-sectional view of a root pump according to a sixth embodiment of the invention;

Fig. 13 is a partly enlarged cross-sectional view of a root pump according to a seventh embodiment of the invention;

Fig. 14 is a partly enlarged cross-sectional view of a root pump according to an eighth embodiment of the

invention;

Fig. 15A is a partly enlarged cross-sectional view of a root pump according to a ninth embodiment of the invention;

Fig. 15B is a cross-sectional view along the line 15B-15B in Fig. 15A;

Fig. 16 is a partly enlarged cross-sectional view of a root pump according to a tenth embodiment of the invention; and

Fig. 17 is a partly enlarged cross-sectional view of a root pump according to an eleventh embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The first embodiment of the invention will be described below with reference to Figs. 1 to 7.

As shown in Figs. 1 and 2, a root pump 11, which functions as a vacuum pump, has a rotor housing member 12, a front housing member 13, and a rear housing member 14. The front housing member 13 is connected to the front end portion of the rotor housing member 12. The rear housing member 14 is connected to the rear end portion of the rotor housing member 12. The rotor housing member 12, the front housing member 13, and the rear housing member 14 constitute the housing of the root pump 11.

The rotor housing member 12 comprises a cylinder block 15 and first to fourth partition walls 16a, 16b, 16c, and 16d. A first pump chamber 51 is defined between the inner wall of the front housing member 13 and the first partition wall 16a. A second pump chamber 52 is defined between the first and second partition walls 16a and 16b. A third pump chamber 53 is defined between the second and

third partition walls 16b and 16c. A fourth pump chamber 54 is defined between the third and fourth partition walls 16c and 16d. A fifth pump chamber 55 is defined between the front end portion of the rear housing member 14 and the fourth partition wall 16d. As shown in Figs. 3 and 4, the cylinder block 15 includes first and second block pieces 17 and 18. Each of the partition walls 16a to 16d comprises a pair of wall pieces 161 and 162.

As shown in Fig. 2, a first rotary shaft 19 is rotatably supported on the front housing member 13 and the rear housing member 14 via two radial bearings 21 and 36. A second rotary shaft 20 is rotatably supported on the front housing member 13 and the rear housing member 14 via two radial bearings 22 and 37. Both rotary shafts 19 and 20 are laid out in parallel to each other. The rotary shafts 19 and 20 are inserted into the first to fourth partition walls 16a to 16d.

First to fifth main rotors 23, 24, 25, 26, and 27, as gas conveying bodies, are formed integrally on the first rotary shaft 19. Sixth to tenth rotors 28, 29, 30, 31, and 32, as gas conveying bodies, are formed integrally on the second rotary shaft 20. The first to tenth rotors 23 to 32 have the same shape and the same size as seen from the direction of axes 191 and 201 of the first and second rotary shafts 19 and 20. The thicknesses of the first to fifth rotors 23 to 27 become gradually smaller in the named order. Likewise, the thicknesses of the sixth to tenth rotors 28 to 32 become gradually smaller in the named order.

The first and sixth rotors 23 and 28 are retained in engagement with one each other in the first pump chamber 51 with a slight clearance maintained. The second and seventh rotors 24 and 29 are likewise retained in engagement with one each other in the second pump chamber 52 with a slight

clearance maintained. In the same manner, the third and eighth rotors 25 and 30 are retained in the third pump chamber 53, the fourth and ninth rotors 26 and 31 are retained in the fourth pump chamber 54, and the fifth and tenth rotors 27 and 32 are retained in the fifth pump chamber 55. The volumes of the pump chambers 51 to 55 become gradually smaller in the named order. The pump chambers 51 to 55 and the rotors 23 to 32 constitute a main pump 49.

As shown in Fig. 2, a gear housing member 38 is attached to the rear housing member 14. Both rotary shafts 19 and 20 penetrate the rear housing member 14 and protrude into the gear housing member 38. First and second gears 39 and 40 are secured to the respective protruding end portions of the rotary shafts 19 and 20 in engagement with each other. An electric motor M is mounted on the gear housing member 38. A motor rotary shaft 33, as a drive shaft, of the electric motor M is coupled to the first rotary shaft 19 via a first shaft coupling 10. The first rotary shaft 19 is rotated in the direction of an arrow R1 in Figs. 3 to 5 by the rotational driving force of the electric motor M. The second rotary shaft 20 rotates in the direction of an arrow R2 in Figs. 3 to 5 by the rotational driving force of the electric motor M.

As shown in Figs. 1, 2, and 4, a passage 163 is formed commonly in the first to fourth partition walls 16a, 16b, 16c and 16d. An inlet 164 to the passage 163 and an outlet 165 from the passage 163 are formed in each of the partition walls 16a to 16d. The first to fifth pump chambers 51, 52, 53, 54, and 55 communicate with one another via the passage 163.

As shown in Figs. 1 and 3, a suction port 171 is

formed in the first block piece 17 in such a way as to communicate with the first pump chamber 51. As shown in Figs. 1 and 5, an exhaust port 181 is formed in the second block piece 18 in such a way as to communicate with the fifth pump chamber 55.

As the first and sixth rotors 23 and 28 rotate, a gas as a fluid, which is fed into the first pump chamber 51 through the suction port 171, is transferred to the second pump chamber 52 from the inlet 164 of the first partition wall 16a through the passage 163 and the outlet 165. The gas is likewise transferred in a similar manner in the order from a pump chamber with a greater volume to one with a smaller volume, i.e., from the second pump chamber 52 to the fifth pump chamber 55 through the third and fourth pump chambers 53 and 54. The gas that has been transferred to the fifth pump chamber 55 is discharged out of the rotor housing member 12 through the exhaust port 181.

As shown in Fig. 5, a part of the fifth pump chamber 55 is defined as a pseudo exhaust chamber 551 by the fifth and tenth rotors 27 and 32. The pseudo exhaust chamber 551 communicates with the exhaust port 181.

As shown in Fig. 1, a flange 41 is connected to the exhaust port 181. Connected to the flange 41 is a muffler 42 to which a guide pipe 43 is connected. Further, an exhaust pipe 44 is connected to the guide pipe 43. The exhaust pipe 44 is further connected to an unillustrated exhaust-gas process system.

A valve body 45 and a return spring 46 are retained in the guide pipe 43. A tapered valve hole 431 is formed in the guide pipe 43. The valve body 45 opens and closes the valve hole 431. The return spring 46 urges the valve body 45 in the direction of closing the valve hole 431. In

the present embodiment, the guide pipe 43, the valve body 45, and the return spring 46 constitute a counterflow prevention mechanism. The pseudo exhaust chamber 551, the exhaust port 181, the flange 41, and the muffler 42 constitute the exhaust space, H, of the main pump 49.

A reciprocating pump 35 serving as an auxiliary pump is attached to the gear housing member 38. The reciprocating pump 35 has a pump housing 34. The pump housing 34 comprises a cylindrical portion 341 and a lid portion 342. One end portion of the rotary shaft 33 of the electric motor M protrudes into the cylindrical portion 341. The reciprocating pump 35 is a diaphragm pump that has a circular diaphragm 56 sandwiched between the cylindrical portion 341 and the lid portion 342, a suction valve 57 for counterflow prevention, a discharge valve 58 for counterflow prevention, and a conversion mechanism 59. The suction valve 57 and the discharge valve 58 are held between a valve presser 68, connected to the lid portion 342, and the inner wall of the lid portion 342. An action chamber 351 is defined between the diaphragm 56 secured to the pump housing 34 and the valve presser 68.

A columnar cam 60 is integrated with one end portion of the motor rotary shaft 33 protruding into the pump housing 34. An annular groove 50 is formed in a peripheral surface 601 of the cam 60 in such a way as to circle around the peripheral surface 601, that is, a circumference of the rotary shaft 33. The annular groove 50 has a component in the direction of an axis 331 of the motor rotary shaft 33. A cylindrical bearing 611 is slidably fitted over the cam 60, which is a part of the motor rotary shaft 33. A cylindrical guide body 61 is fitted in the bearing 611. The guide body 61 supported on the cam 60 via the bearing 611 is slidable in the direction of the axis 331 of the

motor rotary shaft 33 along the peripheral surface 601 of the cam 60. A roller 62 is supported on the cylinder portion of the guide body 61 via a radial bearing 63 in a rotatable manner. The end portion of the roller 62 as a movable body comes into the annular groove 50. An end wall 612 of the guide body 61 is secured fixed to the center portion of the diaphragm 56. The cam 60, the annular groove 50, the guide body 61, the roller 62, and the radial bearing 63 constitute the conversion mechanism 59 for moving the diaphragm 56 as the volume changing body reciprocally in the direction of the axis 331.

A suction passage 64 and a discharge passage 65 are formed in the end wall of the lid portion 342 constituting the pump housing 34 and the valve presser 68. The suction passage 64 communicates with the interior of the flange 41 via a suction pipe 66 while the discharge passage 65 communicates with the interior of the guide pipe 43 via a discharge pipe 67.

As the electric motor M is activated, the motor rotary shaft 33 rotates, and the first and second rotary shafts 19 and 20 rotate according to the rotation of the motor rotary shaft 33. A gas in an unillustrated area that is to undergo a suction action is sucked into the first pump chamber 51 of the main pump 49 via the suction port 171. The gas sucked into the first pump chamber 51 moves toward the fifth pump chamber 55 from the second pump chamber 52 while being compressed. The gas having moved to the fifth pump chamber 55 is discharged into the flange 41 via the exhaust port 181.

As the cam 60 that is a part of the motor rotary shaft 33 rotates, the roller 62 having entered the annular groove 50 is guided relatively along the annular groove 50.

The roller 62 that is supported rotatably by the radial bearing 63 relatively rolls over a side surface 501 and a side surface 502 of the annular groove 50. The roller 62 and the guide body 61 move together toward the axis 331 while undergoing a relative guiding action of the annular groove 50. Fig. 6 shows the roller 62 and the guide body 61 being positioned at the lower dead center farthest from the valve presser 68. In this state, the volume of the action chamber 351 becomes the largest.

As the motor rotary shaft 33 rotates from the state shown in Fig. 6, the roller 62 and the guide body 61 move toward the valve presser 68. When the motor rotary shaft 33 makes a half turn from the state in Fig. 6, the roller 62 and the guide body 61 move to the top dead center closest to the valve presser 68, as shown in Fig. 7. In this state, the volume of the action chamber 351 is minimized. When the motor rotary shaft 33 makes a half turn from the state shown in Fig. 7, the roller 62 and the guide body 61 move to the lower dead center shown in Fig. 6. That is, when the motor rotary shaft 33 makes one turn, the roller 62 and the guide body 61 reciprocate in the direction of the axis 331.

As the guide body 61 moves to the lower dead center from the top dead center, the center portion of the diaphragm 56 secured to the guide body 61 moves together with the guide body 61. Accordingly, the diaphragm 56 moves away from the valve presser 68, increasing the volume of the action chamber 351. As a result, the gas in the exhaust space H pushes the suction valve 57 away and is sucked into the action chamber 351. When the guide body 61 moves to the top dead center from the lower dead center, the diaphragm 56 approaches the valve presser 68, causing the volume in the action chamber 351 to decrease. As a

result, the gas in the action chamber 351 pushes the discharge valve 58 away and is discharged into the guide pipe 43.

The exhaust volume of the reciprocating pump 35 is made smaller than the exhaust volume of the main pump 49.

The embodiment has the following advantages.

(1-1) The gas in the exhaust space H is exhausted by the reciprocating pump 35 with a smaller exhaust volume than the exhaust volume of the main pump 49, so that the pressure in the exhaust space H becomes lower than the pressure in a root pump that has no sub pump. The reduction in pressure in the exhaust space H reduces the pressures in the first to fifth pump chambers 51 to 55. As a result, the consumed power of the root pump 11 becomes lower than that of a root pump without a sub pump.

The reciprocating pump 35, like the main pump 49, acquires the driving force from the electric motor M. That is, the electric motor M is the common drive source for both the reciprocating pump 35 and the drive source of the main pump 49. The structure that does not use an exclusive driving source for the sub pump does not need space for the exclusive driving source for the sub pump and thus suppresses enlargement of the root pump 11. This structure also overcomes the problem of a cost increase which would arise from the additional provision of the exclusive driving source for the sub pump.

The reciprocating pump 35 that brings about the above effects with respect to the root pump 11, which is a vacuum pump, has the conversion mechanism 59 that converts the rotational driving force of the motor rotary shaft 33 to the driving force in the direction of the axis 331 and

reciprocates the diaphragm 56. That is, in the state where the motor rotary shaft 33 rotates, the roller 62 is guided by the annular groove 50 and reciprocates in the direction of the axis 331 of the motor rotary shaft 33, causing the diaphragm 56 to reciprocate in the direction of the axis 331. It is easy to form the annular groove 50 in the peripheral surface 601 of the cam 60 that is a part of the motor rotary shaft 33. The conversion mechanism 59 that has the annular groove 50 is simple in structure and is easy to produce, and the reciprocating pump 35 is simple in structure and is easy to produce.

(1-2) It is possible to construct a conversion mechanism that uses a crank mechanism to reciprocate the diaphragm 56 in the radial direction of the motor rotary shaft 33. However, the use of the crank mechanism needs larger space than the conversion mechanism 59 of the present embodiment that has the annular groove 50. As the roller 62 and the guide body 61 reciprocate in the direction of the axis 331 along the peripheral surface 601 of the cam 60, the conversion mechanism 59 of the embodiment does not require a large moving space. That is, the present embodiment does not require a large space that is needed in the case of the crank mechanism that needs large space around the motor rotary shaft 33, thus the reciprocating pump 35 can be compact.

(1-3) The exhaust volume of the reciprocating pump 35 is determined by the diameter of the diaphragm 56 and the amount of the stroke of the center portion of the diaphragm 56 in the direction of the axis 331. In the case where the exhaust volume of the reciprocating pump 35 is set to the desired volume, the greater the diameter of the diaphragm 56 is set, the smaller the amount of the stroke the diaphragm 56 can be made.

The diaphragm 56 is arranged on the extension line of the motor rotary shaft 33. That is, the diaphragm 56 is arranged in such a way as to cross the axis 331 on the extension line of the motor rotary shaft 33. This layout of the diaphragm 56 can increase the diameter of the diaphragm 56 according to the diameter of the cylindrical portion 341 that constitutes the pump housing 34. That is, as the stroke amount of the diaphragm 56 can be made smaller, a change in the shape of the diaphragm 56 originated from the reciprocation of the diaphragm 56 can be made smaller. The change in the shape of the diaphragm 56 is a change in the bending of that portion of the diaphragm 56 that contacts the periphery of the disk-shaped end portion of the guide body 61 or a change in the bending of the peripheral portion of the diaphragm 56 that contacts the pump housing 34. The smaller the bending change of the diaphragm 56 is, the higher the durability of the diaphragm 56 becomes. The improvement of the durability of the diaphragm 56 increases the reliability of the reciprocating pump 35.

The diameter of the diaphragm 56 can be increased without increasing the shape of the reciprocating pump 35, particularly, the length thereof in the direction of the axis of the motor rotary shaft 33, so much as compared with the mechanism that reciprocates the volume changing body in the direction orthogonal to the output shaft as described in Japanese Patent Laid-Open No. 2001-329963.

(1-4) Reducing the stroke amount of the diaphragm 56 means reduction in the stroke amount of the roller 62 in the direction of the axis 331. While the stroke amount of the roller 62 is determined by the maximum deviation amount, σ, of the annular groove 50 (shown in Figs. 6 and 7),

increasing the maximum deviation amount σ without changing the diameter of the cam 60 increases the maximum inclination angle θ of the annular groove 50 (shown in Figs. 6 and 7). In this case, the load applied to the roller 62 from the side surfaces 501 and 502 of the annular groove 50 becomes larger, which is not desirable for the mechanism that converts the torque to the driving force in the direction of the axis 331.

In the reciprocating pump 35 that makes the stroke amount of the diaphragm 56 smaller by increasing the diameter of the diaphragm 56, it is possible to reduce the maximum inclination angle θ of the annular groove 50 without increasing the diameter of the cam 60. As a result, it is possible to suppress the load applied to the roller 62 from the side surfaces 501 and 502 of the annular groove 50 without increasing the diameter of the cam 60, which would increase the weight of the root pump 11.

(1-5) As the annular groove 50 is formed in such a way as to circle around the peripheral surface 601 of the cam 60, the roller 62 can be allowed to reciprocate the roller 62 in the direction of the axis 331 by continuously rotating the motor rotary shaft 33 in one direction. This can allow the reciprocating pump 35 to operate smoothly.

(1-6) When the roller 62 slides in abutment with the side surfaces 501 and 502 of the annular groove 50, the slide portions of the roller 62 with the side surfaces 501 and 502 are likely to be damaged. The roller 62 that is rotatably supported on the guide body 61 via the radial bearing 63 rolls relatively on the side surface 501 or the side surface 502 according to the rotation of the cam 60. Therefore, the slide portions of the roller 62 with the side surfaces 501 and 502 are not easily damaged.

(1-7) As the motor rotary shaft 33 rotates, the guide body 61 moves in the direction of the axis 331 of the motor rotary shaft 33 while being supported on the cam 60. The structure that supports the guide body 61 by means of the cam 60 eliminates the need for an exclusive support portion for supporting the guide body 61 in the direction of the axis 331 in a movable manner. That is, the cam 60 is suitable as the support portion for the guide body 61.

(1-8) The reciprocating pump 35 is the diaphragm pump that has the suction valve 57, the discharge valve 58, and the diaphragm 56. Because the diaphragm pump has fewer parts and completely inhibits the reverse flow of the gas, the diaphragm pump is simple in structure and is easy to produce. In addition, the diaphragm pump is suitable as a compact reciprocating pump.

(1-9) As the length of the first rotary shaft 19 between the radial bearings 21 and 36 and the length of the second rotary shaft 20 between the radial bearings 22 and 37 are set longer, the following shortcomings would arise.

In the case where the root pump 11 is used side-laid as shown in Fig. 1, the longer the length of the first rotary shaft 19 between both radial bearings 21 and 36, the greater the bending of the rotary shaft 19 between the radial bearings 21 and 36 caused by the weights of the first to fifth rotors 23 to 27 and the weight of the rotary shaft 19. This increases the clearances between the end faces of the first to fifth rotors 23 to 27 and their opposing faces (e.g., for the first rotor 23, the end face of the front housing member 13 and the end face of the partition wall 16a), and lowers the gas transfer efficiency. Such a shortcoming likewise occurs for the second rotary

shaft 20.

The temperature in the rotor housing member 12 becomes higher due to the gas compression. This thermally expands the first rotary shaft 19, making the rotary shaft 19 longer. As the first rotary shaft 19 becomes longer due to the thermal expansion, the first to fifth rotors 23 to 27 change in the direction of the axis 191 of the first rotary shaft 19. The changes in the first to fifth rotors 23 to 27, if large, may cause interference between the opposing faces to those end faces (e.g., for the first rotor 23, the end face of the front housing member 13 and the end face of the first partition wall 16a) and the first to fifth rotors 23 to 27. In the case where the changes in the first to fifth rotors 23 to 27 are large, therefore, it is necessary to set the clearances between the end faces of the first to fifth rotors 23 to 27 and their opposing faces large beforehand. The presetting of the clearances would however lower the gas transfer efficiency. Such a shortcoming likewise occurs for the second rotary shaft 20.

With the structure that acquires the driving force of the reciprocating pump 35 from the cam 60 provided on the motor rotary shaft 33, it is possible to set the length of the first rotary shaft 19 between the radial bearings 21 and 36 and the length of the second rotary shaft 20 between the radial bearings 22 and 37 to the minimum lengths required without considering the existence of the reciprocating pump 35. This can allow the clearances between the end faces of the first to tenth rotors 23 to 32 and the opposing faces to the end faces to be set smaller, and can thus avoid reduction in gas transfer efficiency.

(1-10) As the guide body 61 rotates about the cam 60, the movement of the guide body 61 in the direction of the

axis 331 of the motor rotary shaft 33 does not take place smoothly. As the guide body 61 is fixed to the diaphragm 56 secured to the pump housing 34, the rotation of the guide body 61 about the cam 60 is inhibited. Accordingly, the rotational motion of the cam 60 is smoothly converted to the reciprocal motion of the guide body 61 via the engagement of the annular groove 50 with the roller 62, thus causing the guide body 61 to reciprocate smoothly. In the embodiment, the diaphragm 56, itself, serves as a baffle mechanism.

The second embodiment of the present invention will be discussed with reference to Fig. 8. Like or same reference symbols are given to those components of the second embodiment that are the same as the corresponding components of the first embodiment in Figs. 1 to 7.

A reciprocating pump 35A has a pump housing 34A formed integrally. The valve presser 68 has a cylinder 681 formed integrally. A guide body 61A is fitted in the cylinder 681 slidably but non-rotatably. The unrotatable structure is acquired by, for example, forming the guide body 61A in a horn shape and forming the inner surface of the cylinder 681 in the same horn shape as the shape of the guide body 61A. The unrotatable structure can also be acquired by providing one of a projection and a recess portion (both not shown), which are parallel to the axis 331 and engage with each other on the outer surface of the guide body 61A, and providing the other one on the inner wall of the cylinder 681. The guide body 61A and the cylinder 681 constitute a baffle mechanism.

The guide body 61A is supported on the cam 60 via the bearing 611. The guide body 61A serves the same role as the guide body 61 in the embodiment in Figs. 1 to 7, and as

the cam 60 rotates, the guide body 61A moves in the direction of the axis 331. The guide body 61A defines an action chamber 682 in the cylinder 681. The guide body 61A functions as a piston or a volume changing body. The cam 60, the annular groove 50, the roller 62, the radial bearing 63 and the guide body 61A constitute a conversion mechanism 59A for moving the guide body 61A as a volume changing body reciprocally in the direction of the axis 331.

The present embodiment has advantages similar to those given in paragraphs (1-1), (1-2), (1-4) to (1-7), (1-9), and (1-10) of the first embodiment in Figs. 1 to 7.

The third embodiment of the present invention will be discussed with reference to Fig. 9. Like or same reference symbols are also given to those components of the third embodiment that are the same as the corresponding components of the first embodiment in Figs. 1 to 7.

The roller 62 included in a part of a reciprocating pump 35B is rotatably supported on a guide body 70 via the radial bearing 63. A radial bearing type rotator 71 is attached to the distal end portion of the roller 62. The rotator 71 as a movable body can enter the annular groove 50 and can relatively roll on the side surfaces 501 and 502 of the annular groove 50. A support bracket 69 is securely fixed to the inner wall of the cylindrical portion 341 of the pump housing 34, and the guide body 70 is supported, at both sides, on the support bracket 69 in such a way as to be slidable in the direction of the axis 331. The annular groove 50, the roller 62, the radial bearing 63, the support bracket 69, and the guide body 70 constitute a conversion mechanism 59B for moving the diaphragm 56 as a volume changing body reciprocally in the direction of the axis 331. In the present embodiment, the support bracket

69 and the guide body 70 consitute a baffle mechanism.

The present embodiment has advantages similar to those given in paragraphs (1-1) to (1-6), (1-8), and (1-9) of the first embodiment in Figs. 1 to 7.

The fourth embodiment of the present invention will be discussed with reference to Fig. 10. Like or same reference symbols are also given to those components of the fourth embodiment that are the same as the corresponding components of the first embodiment in Figs. 1 to 7.

A bracket 72 is fixed to the inner wall of the cylindrical portion 341 of the pump housing 34 that constitutes a reciprocating pump 35C. A lever 73 having a V-shaped cross section is rotatably supported on the bracket 72 via a support shaft 721. A rotator 74 is rotatably supported on the distal end portion of a first arm 731 of the lever 73 as a guide body. A guide pin 75 is attached to the distal end portion of a second arm 732 of the lever 73. A transmission body 76 is fixed to the center portion of the diaphragm 56. A guide hole 761 elongated in the radial direction of the diaphragm 56 is formed in the transmission body 76 and the guide pin 75 is inserted in the guide hole 761.

As the motor rotary shaft 33 rotates, the rotator 74 as a movable body traces an arc about the support shaft 721 while being relatively guided along the annular groove 50. The moving direction of the rotator 74 is close to the direction of the axis 331. The movement of the rotator 74 turns the lever 73 about the support shaft 721, causing the guide pin 75 to trace an arc about the support shaft 721. The moving direction of the guide pin 75 that traces the arc is close to the direction of the axis 331. The guide

pin 75 that is in the guide hole 761 urges the transmission body 76 in the direction of the axis 331 and moves the transmission body 76 in the direction of the axis 331. This movement causes the center portion of the diaphragm 56 to move in the direction of the axis 331, thus changing the inner volume of the action chamber 351.

The annular groove 50, the rotator 74, the lever 73, the guide body 75, and the transmission body 76 constitute a conversion mechanism 59C for moving the diaphragm 56 as a volume changing body reciprocally in the direction of the axis 331. In the present embodiment, the bracket 72, the support shaft 721, and the lever 73 constitute a baffle mechanism.

The present embodiment has advantages similar to those given in paragraphs (1-1), (1-3) to (1-6), (1-8), and (1-9) of the first embodiment in Figs. 1 to 7.

The fifth embodiment of the present invention will be discussed with reference to Fig. 11. Like or same reference symbols are also given to those components of the fifth embodiment that are the same as the corresponding components of the first embodiment in Figs. 1 to 7.

First and second annular grooves 50 and 50D are formed in the peripheral surface 601 of the cam 60 that constitutes a part of a reciprocating pump 35D in such a way as to be adjacent to each other in the direction of the axis 331. First and second rollers 62 and 62D are rotatably supported on the guide body 61 via respective radial bearings 63 and 63D. The first roller 62 as a movable body engages with the interior of the first annular groove 50, and the second roller 62D as a movable body engages with the interior of the second annular groove 50D.

There is a phase difference of 180° between the first annular groove 50 and the second annular groove 50D. The first roller 62 and the second roller 62D are arranged at opposite positions with the axis 331 in between. When the peripheral surface of the first roller 62 rolls on the side surface 501 of the first annular groove 50, the peripheral surface of the second roller 62D rolls on the side surface 501 of the second annular groove 50D, and when the peripheral surface of the first roller 62 rolls on the side surface 502 of the first annular groove 50, the peripheral surface of the second roller 62D rolls on the side surface 502 of the second annular groove 50D.

The cam 60, both annular grooves 50 and 50D, the guide body 61, both rollers 62 and 62D, and both radial bearings 63 and 63D constitute a conversion mechanism 59D for moving the diaphragm 56 as a volume changing body reciprocally in the direction of the axis 331.

The present embodiment has the following advantage in addition to the advantages of the first embodiment in Figs. 1 to 7.

The torque of the motor rotary shaft 33 is converted to the driving force in the direction of the axis 331 through the engagement of the pair of annular grooves 50 and 50D with the pair of rollers 62 and 62D at two locations. As the engagement portions of the pair of annular grooves 50 and 50D with the pair of rollers 62 and 62D are located at the opposite positions with the axis 331 in between, an eccentric load is not applied to the guide body 61. As a result, the guide body 61 can move smoothly in the direction of the axis 331.

The sixth embodiment of the present invention will be

discussed with reference to Fig. 12. Like or same reference symbols are given to those components of the sixth embodiment that are the same as the corresponding components of the embodiments in Figs. 1 to 8.

A reciprocating pump 35E uses a bellows 77 instead of a diaphragm. The volume of an action chamber 771 in the bellows 77 is changed by the reciprocation of the guide body 61 in the direction of the axis 331.

The present embodiment has advantages similar to those given in paragraphs (1-1), (1-2), (1-4) to (1-7), (1-9), and (1-10) of the first embodiment in Figs. 1 to 7. The embodiment further has the following advantage. The reciprocating pump 35E is a bellows pump having the suction valve 57, the discharge valve 58 and the diaphragm 56. Because the bellows pump has fewer components and completely inhibits the reverse flow of the gas, it has a simple mechanism and is easy to produce, and is suitable as a compact pump.

The seventh embodiment of the present invention will be discussed with reference to Fig. 13. Like or same reference symbols are also given to those components of the seventh embodiment that are the same as the corresponding components of the first embodiment in Figs. 1 to 7.

A guide body 78 that constitutes a reciprocating pump 35F rotatably supports the roller 62 via the radial bearing 63. A guide rod 781 is formed on the guide body 78. A guide hole 602 is formed in the cam 60 in such a way as to be positioned over the axis 331. The guide rod 781 is slidably fitted in the guide hole 602. When the motor rotary shaft 33 rotates, the roller 62 is urged in the direction of the axis 331, causing the guide body 78 to

reciprocate in the direction of the axis 331 while being guided to the guide hole 602. The cam 60, the annular groove 50, the guide body 78, the roller 62, and the radial bearing 63 constitute a conversion mechanism 59F for moving the diaphragm 56 as a volume changing body reciprocally in the direction of the axis 331.

The present embodiment has the same advantages as those of the first embodiment in Figs. 1 to 7.

The eighth embodiment of the present invention will be discussed with reference to Fig. 14. Like or same reference symbols are also given to those components of the eighth embodiment that are the same as the corresponding components of the first embodiment in Figs. 1 to 7.

A support screw 79 is fastened to a cylindrical guide body 61G that constitutes a part of a reciprocating pump 35G. A hemispherical recess 791 is formed in the distal end face of the support screw 79. A ball 80 as a movable body is rotatably fitted in the recess 791. An annular groove 50G is formed in the peripheral surface 601 of a cam 60G. The ball 80 is rotatably placed in the annular groove 50G. The annular groove 50G and the ball 80 serve roles similar to those of the annular groove 50 and the roller 62 of the first embodiment. As the motor rotary shaft 33 rotates, the guide body 61G reciprocates in the direction of the axis 331. The cam 60G, the annular groove 50G, the guide body 61G, and the ball 80 constitute a conversion mechanism 59G for moving the diaphragm 56 as a volume changing body reciprocally in the direction of the axis 331.

The present embodiment has advantages similar to those given in paragraphs (1-1) to (1-5) and (1-7) to (1-10) of the first embodiment in Figs. 1 to 7.

The ninth embodiment of the present invention will be discussed with reference to Figs. 15A and 15B. Like or same reference symbols are also given to those components of the ninth embodiment that are the same as the corresponding components of the first embodiment in Figs. 1 to 7.

A cylindrical portion 613 is formed in the end wall 612 of a cylindrical guide body 61H, which constitutes a part of a reciprocating pump 35H, along the axis 331. A cylindrical hole 614 of the cylindrical portion 613 is formed in such a way as to penetrate the end wall 612 and a holding piece 81 is fitted in the cylindrical hole 614. The holding piece 81 has a large-diameter portion 811 connectable to the inner wall of the end wall 612 and a small-diameter portion 812 fitted in the cylindrical hole 614 of the cylindrical portion 613. The outside diameter of the large-diameter portion 811 is greater than the inside diameter of the cylindrical portion 613.

A pair of fixing plates 82 and 83 is connected to the diaphragm 56. The diaphragm 56 and the fixing plates 82 and 83 are secured to the holding piece 81 by fastening a screw 84 fastened to the small-diameter portion 812 of the holding piece 81. The cylindrical portion 613, which is a part of the guide body 61H, is held in a relatively rotatable manner between the large-diameter portion 811 of the holding piece 81 and the diaphragm 56 in the direction of the axis 331. That is, even when the guide body 61H rotates, the rotation of the guide body 61H is not transmitted to the holding piece 81.

A rotation receiving body 85H is securely fixed to the inner wall of the cylindrical portion 341 that

constitutes the pump housing 34. A guide groove 851 is formed in the rotation receiving body 85H in such a way that its lengthwise direction is parallel to the axis 331. A pin 86, as a projection portion, is protrusively provided on the outer surface of the guide body 61H. The pin 86 is fitted in the guide groove 851. As the pin 86 is movable in the lengthwise direction of the guide groove 851, the guide body 61H can move in the direction of the axis 331. The torque that acts to rotate the guide body 61H about the cam 60 that is a part of the motor rotary shaft 33 is received by the rotation receiving body 85H through the engagement of the pin 86 with the side wall of the guide groove 851. In the present invention, the guide groove 851 and the pin 86 constitute a baffle mechanism.

When the guide body 61H moves forward in the direction of the axis 331 (rightward from the left side in Fig. 15A), the forward movement is transmitted to the diaphragm 56 through the engagement of the distal end of the cylindrical portion 613 with the fixing plate 82. As a result, the diaphragm 56 moves in the direction of discharging the gas out of the action chamber 351. When the guide body 61H moves backward in the direction of the axis 331 (leftward from the right side in Fig. 15A), the backward movement is transmitted to the diaphragm 56 through the engagement of the inner wall of the end wall 612 with the large-diameter portion 811. As a result, the diaphragm 56 moves in the direction of sucking the gas into the action chamber 351.

The present embodiment has the following advantages in addition to the advantages of the first embodiment in Figs. 1 to 7.

(9-1) The motor rotary shaft 33 is rotated in the

direction of an arrow R1 in Figs. 3 to 5, i.e., in the direction of an arrow Q (shown in Fig. 15B). When the guide body 61H is making the forward movement and the diaphragm 56 is bent on the top dead center side (the state shown in Fig. 7), therefore, the guide body 61H receives the moment in the direction of the arrow Q (shown in Fig. 15B) about the axis 331 by the reaction force of the diaphragm 56. When the guide body 61H is making the backward movement and the diaphragm 56 is bent on the top dead center side, the guide body 61H receives the moment reverse to the direction of the arrow Q about the axis 331 by the reaction force of the diaphragm 56. At the time the guide body 61H shifts the movement from the forward movement to the backward movement, therefore, the moment about the axis 331 with respect to the guide body 61H is switched to the direction opposite to the direction of the arrow Q from the direction of the arrow Q.

When the guide body 61H is making the backward movement and the diaphragm 56 is bent on the bottom dead center side, the guide body 61H receives the moment in the direction of the arrow Q about the axis 331 by the reaction force of the diaphragm 56. When the guide body 61H is making the forward movement and the diaphragm 56 is bent on the bottom dead center side (the state shown in Figs. 6 and 15), the guide body 61H receives the moment reverse to the direction of the arrow Q about the axis 331 by the reaction force of the diaphragm 56. At the time the guide body 61H shifts the movement from the backward movement to the forward movement, therefore, the moment about the axis 331 with respect to the guide body 61H is switched to the direction opposite to the direction of the arrow Q from the direction of the arrow Q.

When the guide body 61H is making the forward

movement and the diaphragm 56 is shifted from the state bent on the bottom dead center side to the state bent on the top dead center side, the moment about the axis 331 with respect to the guide body 61H is switched to the direction of the arrow Q from the direction opposite to the direction of the arrow Q. When the guide body 61H is making the backward movement and the diaphragm 56 is shifted from the state bent on the top dead center side to the state bent on the bottom dead center side, the moment about the axis 331 with respect to the guide body 61H is switched to the direction of the arrow Q from the direction opposite to the direction of the arrow Q.

In the embodiment in Figs. 1 to 7, the aforementioned moment directly influences the diaphragm 56 so that the diaphragm 56 receives the twisting force about the axis 331. The twisting force is one factor to reduce the service life of the diaphragm 56.

In the embodiment in Figs. 1 to 7, the switching of the moment directly influences the diaphragm 56, thus switching the direction of action of the twisting force on the diaphragm 56. The switching of the direction of action occurs four times per one rotation of the motor rotary shaft 33, and the number of times the switching of the direction of action occurs per unit time is proportional to the number of rotations of the motor rotary shaft 33 per unit time. The switching of the direction of action that is repeated reduces the service life of the diaphragm 56.

In the ninth embodiment, as the guide body 61H is rotatable with respect to the holding piece 81 secured to the diaphragm 56, the influence of the moment on the diaphragm 56 does not take place. Nor does the aforementioned switching of the direction of action take

place. As a result, the durability of the diaphragm 56 in the reciprocating pump 35H in the present embodiment becomes greater than the durability of the diaphragm 56 in the reciprocating pump 35 in the first embodiment. Furthermore, in the present embodiment, the baffle mechanism constituted by the guide groove 851 and the pin 86 certainly absorbs the moment on the diaphragm 56. Also, in the embodiments of Fig. 9 and 10, each baffle mechanism, which does not include the diaphragm 56, certainly absorbs the moment on the diaphragm 56.

The tenth embodiment of the present invention will be discussed with reference to Fig. 16. Like or same reference symbols are also given to those components of the tenth embodiment that are the same as the corresponding components of the first embodiment in Figs. 1 to 7.

In a reciprocating pump 35J, a support cylinder portion 615, as a projection portion, which supports the radial bearing 63, is engaged with the guide groove 851 of a rotation receiving body 85J. The guide groove 851 guides the support cylinder portion 615 in the direction of the axis 331. In the present embodiment, the guide groove 851, and the support cylinder portion 615 constitute a baffle mechanism.

The present embodiment has the same advantages as those of the embodiment in Figs. 15A and 15B.

The eleventh embodiment of the present invention will be discussed with reference to Fig. 17. Like or same reference symbols are given to those components of the eleventh embodiment that are the same as the corresponding components of the embodiment in Figs. 15A and 15B.

A spring 87 is retained in the action chamber 351 of a reciprocating pump 35K. The spring 87 urges the diaphragm 56 toward the guide body 61. The diaphragm 56 is pressed against the end wall 612 of the guide body 61 by the spring force of the spring 87. As the guide body 61 moves forward, the diaphragm 56 moves in the direction discharging the gas out of the action chamber 351 against the spring force of the spring 87. As the guide body 61 moves backward, the diaphragm 56 follows up the movement of the guide body 61 and moves in the direction sucking the gas into the action chamber 351 by the spring force of the spring 87.

The diaphragm 56 is coupled to the guide body 61 by the spring force of the spring 87. The end wall 612 of the guide body 61 only contacts the diaphragm 56 in a slidable manner. As in the case of the embodiment in Figs. 15A and 15B, therefore, the influence of the moment on the diaphragm 56 does not take place. Nor does the aforementioned switching of the direction of action take place. As a result, the durability of the diaphragm 56 in the reciprocating pump 35K in the present embodiment becomes greater than the durability of the diaphragm 56 in the reciprocating pump 35 in the first embodiment.

The embodiment may be modified in the following manners.

It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

In the embodiment in Fig. 9, the radial bearing 63

may be omitted and the roller 62 may be directly coupled to the guide body 70.

In the embodiments in Figs. 1 to 17, a ball valve body may be used instead of the plate-like suction valve 57 and discharge valve 58.

In the embodiment in Figs. 1 to 7, the diaphragm 56 may be pressed against the guide body 61 by urging means, such as a spring, from the action chamber (351) side to couple the diaphragm 56 to the guide body 61 as per the embodiment as shown in Fig. 16.

In the embodiment in Figs. 15A and 15B, the small-diameter portion 812 of the holding piece 81 may be integrated with the fixing plate 82 so that the large-diameter portion 811 of the holding piece 81 is formed separate from the small-diameter portion 812. In this case, the screw 84 has only to be fastened to the large-diameter portion 811.

In the embodiment in Figs. 15A and 15B, the fixing plate 82 may be omitted.

In the embodiment in Fig. 16, the roller 62 may be protruded outward from the radial bearing 63, and the protruding end portion of the roller 62 may be engaged with the groove of the rotation receiving body. In this case, the roller 62 and the groove of the rotation receiving body constitute a baffle mechanism and the roller 62 becomes the projection portion on the pump housing (34) side.

In the embodiment in Fig. 17, a thrust bearing may be intervened between the diaphragm 56 and the guide body 61.

In the embodiments in Figs. 15A and 15B, Fig. 16, and Fig. 17, a projection portion may be provided on the pump housing (34) side and a guide groove may be provided on the guide body side, both constituting a baffle mechanism.

The reciprocating pump of the present invention may be used as a sub pump in other vacuum pumps (e.g., a screw pump) than the root pump.

The present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.